OC-0058

A novel 4DCT technique for breathing motion modeling

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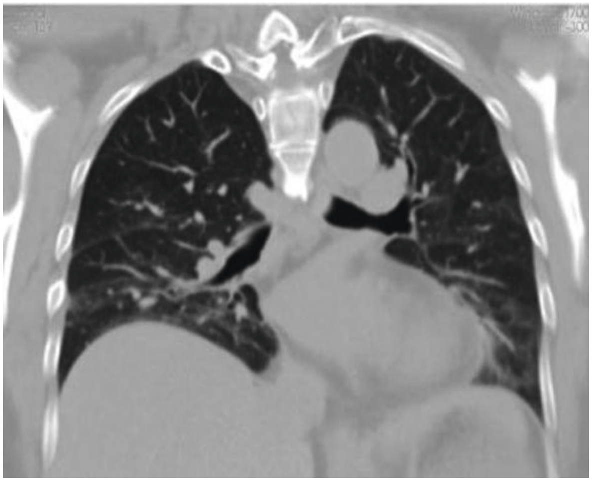
Purpose/Objective: To develop a novel method for 4DCT data acquisition that avoids the pitfalls of existing methods, including abutment discontinuities, management of irregular breathing, and high dose.

Materials and Methods: The proposed 4DCT method uses simultaneous breathing surrogate measurement (pneumatic bellows around the abdomen) and standard fast helical scanning to acquire the breathing-correlated CT scans. The CT scanner is operated in standard helical mode using a pitch of 1, the fastest rotation rate (<0.3s), low mAs (40mAs) and covering the lungs. The scans acquisition is repeated 25 times, switching scanning directions between successive acquisitions. The scans take roughly ¼ of the breathing cycle to acquire, so no image corresponds to any specific breathing phase. Instead, each CT slice is correlated with a specific time and therefore phase. We use deformable image registration to determine the locations of tissues in the 25 scans. The registration maps indicate the tissue motion as a function of the measured breathing phase. We utilize the 5D breathing motion model, which correlates motion to the breathing amplitude (surrogate voltage) and its derivative. The motion model is used to determine the motion paths taken by the tissues during respiration. Because all of the images are coregistered, they are deformed to a single reference image geometry and averaged, reducing the statistical image noise. The motion model allows that aggregate image to be deformed to a user-specified breathing phase.

Results:



Because the images were acquired during quiet respiration and with rapid helical scanning, the images were motion artefact free and the coregistration accuracy was better than 1 mm. The figure shows an example of a reconstruction of an exhalation image. Note that there are no obvious motion or abutment artefacts typical of commercial 4DCT techniques. This technique has allowed us to measure the breathing motion model so that the correspondence of the model to the deformed tissues is 0.4 mm ± 0.6 mm.

Conclusions: The proposed 4DCT acquisition and analysis technique promises to improve the clinical and research applications of breathing motion management, producing artefact-free images and the ability to generate low-noise images at arbitrary breathing phases. Determination of breathing motion model parameters is greatly improved with the proposed technique and we are developing it into a replacement for the current clinical 4DCT protocols.

OC-0059

Motion compensated Digital Tomosynthesis using an a priori motion model

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Purpose/Objective: Gantry mounted kV imaging systems allow inline Digital Tomosynthesis (DTS) to monitor intrafraction motion during VMAT delivery.[1] Respiratory motion in the thorax and upper abdominal region, however, blurs DTS images, potentially compromising monitoring accuracy. Motion compensated (MC) DTS has the potential to mitigate such motion artifacts. The purpose of this study was therefore to implement MC-DTS and evaluate the registration accuracy for normal and MC DTS.

Materials and Methods: An a-priori motion model (4D deformation-vector-field (DVF)) was calculated from the 4D planning CT which was forced to be zero on average to ensure a MC-DTS with each organ in its time averaged mean position. During DTS reconstruction, the respiratory phase was calculated for each projection image, the corresponding DVF extracted from the motion model and applied to deform the back-projection to the Mid-Position geometry.

To evaluate MC DTS, both static and moving scans were made of the dynamic thorax phantom (CIRS, Norfolk, Virginia, USA). The motion pattern was sin^6 with a peak-to-peak (pp) amplitude of 2 cm in the CC direction and a 1 cm pp sinus in the AP direction. Scans were acquired over an arc of 360°, with overlapping 30° DTS reconstructions every 10°.

Both conventional and MC-DTS images were registered to the corresponding 30 degree static DTS using correlation ratio as a cost function. The registration only optimized 2D translations in the imaging beam's eye view based on a 3D-rectangular region of interest defined around the spherical phantom insert in the static reference scan.

Results: Visual inspection shows that the motion blur is strongly reduced using MC-DTS (figure 1). The translations found for the DTS were CC -2.30 ± 1.29 mm, LR 0.12 ± 0.54 mm and AP -0.21 ± 1.06 mm (mean ± 1 SD). For the MC-DTS the translations were CC -0.02 ± 0.20 mm, LR 0.09 ± 0.33 mm and AP -0.01 ± 0.21 mm. The translational difference was significant for the CC ($p<0.001$) but not for the AP/LR direction. For two gantry angles registration outliers were removed from the analysis.

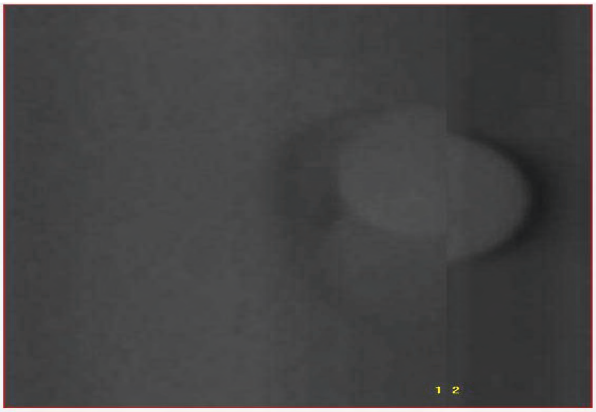

Figure 1: A conventional DTS (1) and motion compensated DTS (2) image of 30 degree of the phantom in the imaging beam's eye view. Motion blur in both CC and AP direction is minimized in MC-DTS.

Conclusions: Motion compensation considerably reduced motion blur in DTS images and improved registration with static reference DTS images allowing more accurate DTS guidance and intra-fraction monitoring concurrent with VMAT delivery.

[1] M. van Herk et al., On-line digital tomosynthesis for patient stability monitoring during VMAT delivery for SBRT of lung cancer, ESTRO 2012

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Workflow automation for ultrafast kilovoltage-megavoltage cone-beam CT for image guided radiotherapy

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Purpose/Objective: Combined kilovoltage-megavoltage cone-beam CT (kV-MV CBCT) enables CBCT imaging of lung tumors during breath-hold. We established synchronized kV-MV imaging based on a 90° angle interval for kV and MV projections that are acquired simultaneously within 15 seconds, which roughly corresponds to one breath-hold phase in most patients. The previous workflow that was already established to provide proof-of-principle included extensive manual interaction and was therefore not feasible for a potential clinical application.This abstract presents a novel concept for a fully automatic setup that has been established recently.

Materials and Methods: In accordance with the vendor a clinical treatment unit (Elekta Synergy) was modified with dedicated hardware (in-house development) which allows simultaneous and synchronized kV-MV imaging. This hardware can be activated by a key